BRIEFER ARTICLES

THE PHYSIOLOGICAL CONSTANTS OF PLANTS COMMONLY USED IN AMERICAN BOTANICAL LABORATORIES

The object of this paper is identical with that of its predecessor,[1] namely, to ascertain which of the plants commonly grown or readily raised in greenhouses is best adapted for the demonstration of a particular physiological process, and how much may be expected of it and of the others. The work is being done in the Laboratory of Plant Physiology at Smith College, with the advice of Professor W. F. Ganong. Others of the series are in advanced preparation.

II. ROOT PRESSURE AND EXUDATION

Osmotic processes, of course, are of the greatest importance in the life of the plant, and of these osmotic root absorption is perhaps best known. The most direct way of demonstrating the osmotic absorption and pressure of the root is by measurement of the quantity and pressure of exudation from the stem cut just above the ground. I have undertaken to find for those greenhouse plants which are practicable for the purpose the pressure of root exudation and the quantity exuded. The only work of importance done upon potted plants, so far as I can find, is that of Wieler[2] in 1892, who recorded the pressures of some fifteen greenhouse plants, and this is the source of the figures in current books. Single measurements have also been made by Detmar and a few others. The pressures given by trees lie outside the present work.

The first requisite for the study of exudation pressure is a gauge which will register the pressure accurately, however small the quantity of liquid exuded. Most of those used for demonstration are faulty in principle to an extreme degree, as has been recently pointed out.[3] After some preliminary trials, I have fixed upon one which is practically that described by Morse and Fraser[4] for the measurement of osmotic pressures. It is a mercury manometer of the usual form, of 0.5^{mm} bore barometer tubing, with a bulb blown in the middle arm. In order to test the variations in

1 Bot. Gazette 40:302–305. 1905.

2 Cohn's Beiträge zur Biologie der Pflanzen 6:1–210. 1892.

3 W. F. Ganong in School Science and Mathematics 6:300. 1906.

4 Am. Chem. Jour. 34:3–5. 1905.

the diameter of the bore, two gages were calibrated. It was found, however, that while for high pressures, involving the measurement of short lengths of tube, it would be necessary to make the correction for the differences in diameter of the bore, this is not needed in dealing with small pressures, of about one atmosphere, because in the length of tube used the inequalities, which are very slight, balance one another.

For use the gage is first filled with clean, dry mercury; then with the lower end dipping into boiled water mercury is forced out into the water by pressure with a rubber bulb upon the upper end until there remains only the required amount, namely, enough to fill the gage half-way up the bulb. When the force is removed, water replaces the mercury in the lower end. The long arm is then filled with air, dried, by being drawn through tubes containing calcium chlorid and phosphorus pentoxid, and is quickly sealed with hot, melted shellac. Proper tests were of course applied to prove that the shellac made a perfectly tight joint with the glass. Sealing wax was used at first, but it is apt to crack from the glass when the range of temperature is great. The gage was then attached by means of stout-walled rubber tubing to the stump of a plant whose top had been cut off $2-3^{cm}$ above the ground. The cutting was done under water to prevent the entrance of air, which would rise in the gage later. The rubber tubing was fastened on the stump with stretched rubber bands, or wire in case of a stout stem, and to the manometer by wire and was wound with tire-tape to prevent stretching under internal pressure.[5]

Where the stem was larger than the gage, a glass sleeve was cemented with sealing-wax outside the latter, to make it nearly the size of the stem. The height of the mercury in the long arm was noted and when it had reached its highest point the pressure was computed by BOYLE's law. A source of error in the use of the gage, not noted until too late for correction, consists in the expansion of the mercury through rise in temperature. Subsequent tests were made to ascertain its extreme possible amount, with a result that under no circumstances could the error exceed 0.0134 atmospheres or 0.2^{lb} per square inch, and in nearly all cases it was very much less than this.

The quantity of exudation was found at the same time for plants of the same age and approximate size as those used in the exudation pressure experiments. For this a piece of glass tubing was attached to the plant and led into a graduated cylinder which contained a film of oil to prevent evaporation.

5 A fuller description of this gage with directions for use is given by W. F. GANONG in a catalogue of apparatus now being published by the Bausch & Lomb Optical Company.

All the plants used were young, in good growing condition, and in most cases were taken just before flowering. It will at once occur to the reader that in some cases conclusions have been drawn from too small a number of plants, but since in these experiments the plants must be sacrificed completely, it was impossible to obtain more than three of some species—one for exudation and two for pressure. However, this does not involve so great a possibility of error as it seems at first sight, for, although it is possible that the plant used may be abnormal, the probabilities, according to QUETELET's law, are that it will fall near the mean. The temperature of the laboratory during observation of the experiments was 18°–22° C. The soil temperature at time of highest pressure was 17°–18°C.

The results obtained for quantity and pressure of exudation are given in the following table, in which the first and fourth columns give the number of plants used for exudation and for pressure experiments, respectively.

From the table on page 53 it will be seen that the plants giving the highest mean pressures, in order of amount, are *Salvia involucrata*, *Helianthus annuus*, *Fuchsia speciosa*, with others following according to the table. When considered in order of maximum pressures, the highest are given by *Fuchsia speciosa*, *Salvia involucrata*, and *Lycopersicum esculentum*. The highest minimum pressures are given by *Helianthus annuus*, *Salvia involucrata*, and *Senecio Petasitis*.

For the practical purpose of demonstration, taking into consideration high pressures, ease of manipulation, and abundance of plants, the very best are *Fuchsia speciosa*, *Chrysanthemum frutescens*, and *Pelargonium zonale*. Since they have stout, woody stems, there is no danger of compressing the vessels in making a tight joint with the pressure gauge. With the pressure gauge attached they maintain a high pressure for about a week, usually giving the highest pressure between 10 and 12 o'clock on the second day. The next best are *Heliotropium peruvianum*, *Pelargonium peltatum*, and Abutilon. These give lower pressures than the preceding, but they have a slight advantage in another way. The stems of vigorous young plants have about the same diameter as the manometer tubing and therefore can be more readily attached to the gauge. Other plants which give high pressures are *Lycopersicum esculentum* and *Phaseolus vulgaris*. These have somewhat soft stems, though with care it is not difficult to attach the gauge.

The following plants cannot be used advantageously for this experiment: *Euphorbia pulcherrima*, because of its latex which thickens and closes the ducts in a very short time; *Ricinus communis*, because of its hollow stem; *Senecio mikanioides* and *Tropaeolum majus*, because their

Name	No. of plants	Exudation quantity in cc.	Durat'n of flow in days	No. of plants	Pressure in atmospheres
		Min. Mean Max.			Min. Mean Max.
Abutilon (golden bells)...	3	1 – 1.9–3.3	2–3	4	.757– .795– .840
Begonia coccinea........	1	168	29	2	.818– .858– .898
Chrysanthemum frutescens (marguerite).....	4	24 –40 – 55	9–21	4	.847–1.014–1.230
Coleus................	2	11.5–14.2– 17	8–9	2	.822– .897– .972
Cucurbita Pepo (squash)	1	27	12		
Euphorbia pulcherrima (poinsettia)..........	1	2.5	1	2	.573– .637– .701
Ficus elastica (rubber plant)...............	1	23	31	2	.737– .817– .897
Fuchsia speciosa.......	6	16.5–99.2–263	12–34	8	.887–1.246–1.605
Hedera Helix (English ivy)..................	1	1.5	2	2	.323– .430– .538
Helianthus annuus (sunflower)...............	1	30	16	2	1.210–1.276–1.343
Heliotropium peruvianum (heliotrope).....	1	7	8	4	.809–1.045–1.294
Impatiens Holstii........	1	3	3	2	.851– .855 .860
Lupinus albus (white lupine)...............	1	4	3	2	.793– .807– .821
Lycopersicum esculentum (tomato-dwarf stone)...............	1	13	5	4	1.015–1.164–1.349
Pelargonium domesticum (Lady Washington geranium)........	1	17.4	13	2	.714– .861– .909
Pelargonium peltatum (ivy-leaved geranium)	1	4.5	9	2	.940–1.001–1.063
Pelargonium zonale (horse-shoe geranium)	3	14–15.5–17.5	19–20	10	.620– .881–1.116
Phaseolus vulgaris (string bean).........	2	4– 4.2– 4.5	5	4	.908–1.002–1.149
Ricinus communis (castor bean)............	1	8.5	17	2	.666– .692– .718
Salvia involucrata.......	1	14	12	2	1.151–1.369–1.571
Senecio mikanioides (German ivy)........	1	27	7	2	.518– .633– .648
Senecio Petasitis........	1	110	14	2	1.137–1.191–1.246
Tropaeolum majus (nasturtium).............	1	13.5	8	2	.759– .779– .800
Zea Mais..............	1	4	6		

stems are too soft and weak. I could not attach the gauge successfully to the following: *Cucurbita Pepo*, *Zea Mais*, and *Vicia Faba*. Obviously stemless plants cannot be used. Thus comparatively few of the common plants are practicable.

The minimum pressures for any given plant in the table were obtained in the winter months and the maximum pressures in April and May, showing a variation in pressure with time of year which is probably widespread.

In order to determine the individual variations of plants taken at the same time of year and treated in exactly the same way, the following species were studied with appended results:

April, 5 plants Pelargonium zonale, .620, .645, .767, .782, 1.035 atmospheres.
June, 5 plants Fuchsia speciosa, 1.406, 1.428, 1.467, 1.500, 1.605 "

While an average of the pressures given by the above plants may seem of no great value, nevertheless there is a certain advantage in knowing this mean, which may be taken as a general expression of the root pressure of common greenhouse plants. The mean pressure of the 22 plants studied is approximately 0.9 atmosphere, or in round numbers 13^{lb} for the square inch.

Turning from pressure to quantity of exudation, the above table shows that the plants giving the greatest quantity of exudation are *Fuchsia speciosa* and *Begonia coccinea*. Different plants of *Fuchsia speciosa* vary greatly in the quantity given off, and this seems to be correlated with the formation of new shoots—the longer this is delayed the greater the flow. This is true in less degree of most of the plants which form new shoots. In others—*Impatiens Holstii, Lycopersicum esculentum, Pelargonium peltatum,* and *Tropaeolum majus*—the stems decay and the roots soon die.

Some observations were made on periodicity of exudation and of exudation pressure. These facts will be published in a separate note later.—SOPHIA ECKERSON, *Northampton, Mass.*

THE CONDITION OF CERTAIN WINTER BUDS

During 1905–1906 an effort was made to ascertain the seasonal stages in the microspore development of certain woody plants, with the following results:

	Mother cell stage	Dividing nuclei	Mature spores
Populus deltoides	....	....	October 23
Fraxinus americana	Oct. 23—Feb. 15	....	....
Celtis occidentalis	October 24	April 12	April 15
Carpinus caroliniana	October 24	April 12	April 15
Cornus florida	August 20	August 22	August 24
Cercis canadensis	October 31	April 17	April 20

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